U.S. Air Force Fact Sheet

18th Space Control Squadron

Processing Reentries of Space Objects

ABSTRACT

The 18th Space Control Squadron (18 SPCS) predicts when and where man-made objects will reenter the Earth's atmosphere. It does so on behalf of Air Force Space Command (AFSPC), in support of U.S. Strategic Command's Joint Force Space Component Command (JFSCC), which is charged with executing USSTRATCOM's presidentially-assigned Space Operations mission area. This fact sheet presents how 18 SPCS processes reentries, the systems used to do so, current challenges, and the products, notifications and reports issued throughout the process.

1. INTRODUCTION

The 18 SPCS is the tactical unit under the 21st Space Wing (21 SW) responsible for maintaining and providing foundational space situational awareness (SSA) for the U.S. Department of Defense, as well as interagency, commercial and international partners around the globe. The core functions of 18 SPCS include maintaining the space catalog through space surveillance and tracking data received from the U.S. Space Surveillance Network (SSN), generating spaceflight safety data, and processing high-interest events such as launches, reentries, and breakups. In years past, this role was accomplished successively by the Space Control Center (SCC), 1st Space Control Squadron (1 SPCS), and most recently the 614th Air Operations Center (614 AOC), also referred to as the Joint Space Operations Center (JSpOC).

Reentries are defined as man-made objects that are reentering the Earth's atmosphere and will no longer remain in orbit. There are three categories of reentries: reentry assessments (RA), normal decays, and deorbits. Reentry assessment (RA) is the process of maintaining the orbits of reentering objects, predicting the point and time of atmospheric reentry 10 km above the Earth's surface, and notifying the appropriate U.S. and international agencies, as well as the general public of the predictions. RA objects may be classified as routine or high-interest, and include payloads, rocket bodies or platforms, and debris larger than one square meter. Normal decays are objects that decay naturally and not deemed survivable, so they are not treated as an RA unless they are high-interest events. A deorbit is a controlled reentry. The time and location are normally known for a deorbit, and there is little to no predictive data generated. For this reason, deorbits are not normally considered for reentry assessment. The remainder of this fact sheet will focus on RAs.

2. BACKGROUND

While most objects burn up and disintegrate as they decay, some survive reentry of the atmosphere and have the potential to cause damage to people or property, as well as trigger false missile warnings. Consequently, 18 SPCS performs RAs as a spaceflight safety service and to adhere to international agreements. Article 3 of the 1971 "Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War between the

United States of America and the Union of Soviet Socialist Republics” states “The Parties undertake to notify each other immediately in the event of detection by missile warning systems of unidentified objects.” For this reason, the United States reports RAs to foreign governments.

Reentries can become high-interest events if they are historically significant, deemed significant by a higher authority, historically survive or have a radar cross section of greater than or equal to ten square meters, garner significant media interest, have a radioactive/nuclear payload or power source, or contain human remains. Any decay or reentry deemed high-interest by the 18 SPCS Commander will be processed as an RA.

3. 18 SPCS REENTRY PROCESS

The 18 SPCS Analysts perform daily screening of all objects in the space catalog for decay status. Using the 18 SPCS mission system, Space Defense Operations Center (SPADOC), analysts identify upcoming reentries by propagating every object for a period of time or until decay using Simplified General Perturbations 4 (SGP4) Two-Line Elements (TLEs), which is adequate for the near-earth, circular objects. For the highly-eccentric objects, however, a database query is run for objects with a perigee height less than 250 km for near-earth objects and objects with a perigee height less than 200km for deep-space objects. Analysts then determine which objects are most likely to decay and add them to a list for entry into the reentry assessment process, referred to as initialization.

RAs are initialized seven to ten days before predicted reentry for near earth objects and fourteen days before reentry for highly-eccentric objects. Initialization entails creating an SP state vector for the object, upgrading the sensor tasking, and creating a six-part folder for the event. The six-part folder includes all ground traces, a log of all RA runs, messages, and state vectors generated for the event. Required runs are done at the four-day, three-day, two-day, one-day, twelve-hour, six-hour, and two-hour points, as well as post-decay. During a required run, 18 SPCS operators update the state, re-run the decay prediction, and send out appropriate messages. Monitor runs are done between the required runs if new sensor observations are acquired in order to keep the state current. A new reentry prediction is also accomplished.

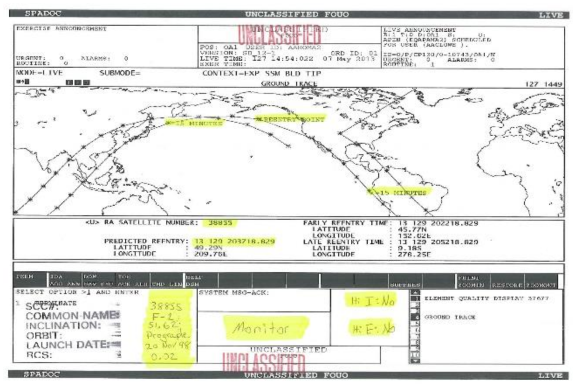


Figure 1. Ground trace of F-1, 38855

The 18 SPCS executes the majority of the RA process using SPADOC, which is their mission system of record for reentries. SPADOC’s Special Perturbations (SP) propagator uses the Higher Order Theory Force (HOTF) model. The 18 SPSC also utilizes the Astrodynamics Support Workstation’s (ASW) SP propagator, which has more up-to-date earth models and a more accurate dynamic atmosphere model.

If an object fragments before it reenters, the RA Officer will catalog pieces with adequate tracking data as analyst objects. Many times, pieces will reenter the atmosphere before they can be cataloged. The pieces that are created will be tasked for radar cross section (RCS) data to determine if the objects are large enough to be considered an RA. Some objects can fragment multiple times prior to reentry. Objects that breakup within six hours of reentry and cross the Commonwealth of Independent States (CIS) or Southwest Asia will be reported to U.S. interagency partners through the operational reporting (OPREP) process.

4. REENTRY CONFIRMATION

The 18 SPCS will confirm the reentry of an object using visual information, if available, by correlating it to ephemeris for the object; this is reported as the official reentry time. In addition, 18 SPCS tasks sensors to perform POS/NEG reporting for passes occurring after the predicted reentry time. If the sensor tracks it based on the most recent TLE, they report "positive" acquisition; if they do not track the object they report "negative" acquisition, also referred to as a "no-show." If visual information is received, only one "no-show" from the tasked sensors is required to confirm the reentry. If no visual information is received, three "no-shows" are required. Alternatively, a reentry can be deemed reentered by the RA officer. After a RA is confirmed as reentered, sensors are de-tasked via the decay message issued by SPADOC.

5. MESSAGING

One of SPADOC's primary functions is to send information to the SSN through automatic messaging. SPADOC sends Tracking and Impact Prediction (TIP) Tasking messages to sensors as a direction to increase tasking at the two- and one-day point. After each required RA run, SPADOC also issues TIP Alert messages, which contain predicted decay time, latitude, and longitude, for transmission to the SSN, as well as JFSCC's public website www.space-track.org, where they are available to the general public.

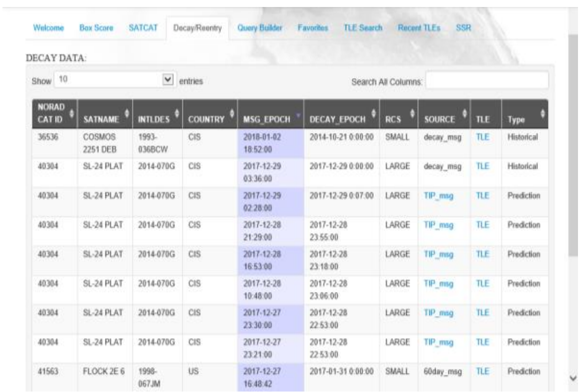
The 18 SPCS will issue an OPREP-3 at the six and two-hour points, and the final runs if the event meets reportable criteria. The OPREP-3 is a standardized military format used to report significant events and incidents to the highest levels of command, as well as interagency partners such as the Department of State and missile warning agencies. OPREP-3 criteria include any high-interest reentry regardless of its survivability, RAs that are predicted to reenter +/- 15 minutes of CIS or Southwest Asia, or if an object breaks up within six hours of reentry and will cross the former Soviet Union. In addition, RAs that are predicted to reenter +/- 15 minutes of the continental US, Alaska, or Hawaii are reported to the U.S. Federal Emergency Management Agency (FEMA).

6. SPACE-TRACK.ORG PRODUCTS

Space-Track.org is JFSCC's public website, which 18 SPCS populates with a variety of SSA data, to include reentry and decay predictions. Anyone who registers for an account on the website may access this information free of charge. The 18 SPCS provides reentry information in three ways as an object progresses through the stages of decay. First, it will appear in the 60-day decay message, which is posted weekly and lists all objects predicted t0 decay within the next sixty days. The times are based off of SGP4 prediction, but can be overwritten by an SP prediction if one has been done.

The second message that goes to Space-Track.org is the TIP Alert message. These are posted after completion of the required runs and include the predicted time and location of impact for the object. This message is only done for RAs, and the prediction is done with the SPADOC SP propagator.

The third, and final, message is the decay message. These are issued on SPADOC to confirm that the object has decayed and is no longer in orbit. Space-Track.org displays this message on the Decay/Reentry page, and is also reflected as the decay date in the satellite catalog.



NORAD CAT ID	SATNAME	INTLDES	COUNTRY	MSG_EPOCH	DECAY_EPOCH	RCS	SOURCE	TLE	Type
36536	COSMOS 2251 DEB	1993-036BCW	CIS	2018-01-02 18:52:00	2014-10-21 0:00:00	SMALL	decay_msg	TLE	Historical
40304	SL-24 PLAT	2014-070G	CIS	2017-12-29 03:36:00	2017-12-29 0:00:00	LARGE	decay_msg	TLE	Historical
40304	SL-24 PLAT	2014-070G	CIS	2017-12-29 02:28:00	2017-12-29 0:07:00	LARGE	TIP_msg	TLE	Prediction
40304	SL-24 PLAT	2014-070G	CIS	2017-12-28 21:29:00	2017-12-28 23:55:00	LARGE	TIP_msg	TLE	Prediction
40304	SL-24 PLAT	2014-070G	CIS	2017-12-28 16:53:00	2017-12-28 23:18:00	LARGE	TIP_msg	TLE	Prediction
40304	SL-24 PLAT	2014-070G	CIS	2017-12-28 10:48:00	2017-12-28 23:06:00	LARGE	TIP_msg	TLE	Prediction
40304	SL-24 PLAT	2014-070G	CIS	2017-12-27 23:30:00	2017-12-28 22:53:00	LARGE	TIP_msg	TLE	Prediction
40304	SL-24 PLAT	2014-070G	CIS	2017-12-27 23:21:00	2017-12-28 22:53:00	LARGE	TIP_msg	TLE	Prediction
41563	FLOCK 2E 6	1998-067JM	US	2017-12-27 16:48:42	2017-01-31 0:00:00	SMALL	60day_msg	TLE	Prediction

Figure 6. Decay tab of space-track.org

NORAD_CAT_ID	MSG_EPOCH	INSERT_EPOCH	DECAY_EPOCH	WINDOW	REV	DIRECTION	LAT	LON	INCL	NEXT_REPORT	ID	HIGH_IN
40304	2017-12-29 02:28:00	2017-12-29 03:11:33	2017-12-29 00:07:00	5	17798	descending	-60	208.5	97.4	0	6787	N
40304	2017-12-28 21:29:00	2017-12-28 21:44:16	2017-12-28 23:55:00	38	17799	descending	-11.2	222.9	97.4	0	6786	Y
40304	2017-12-28 16:53:00	2017-12-28 17:11:09	2017-12-28 23:18:00	60	17799	ascending	35.9	48.5	97.4	2	6785	Y
40304	2017-12-28 10:48:00	2017-12-28 10:52:09	2017-12-28 23:06:00	180	17797	ascending	-12.6	58.5	97.4	6	6784	Y
40304	2017-12-27 23:30:00	2017-12-27 23:35:48	2017-12-28 22:53:00	300	17797	ascending	-62.5	74.3	97.4	12	6783	Y
40304	2017-12-27 23:21:00	2017-12-27 23:28:37	2017-12-28 22:53:00	300	17797	ascending	-62.5	74.3	97.4	12	6782	N
40304	2017-12-26 21:52:00	2017-12-26 21:56:56	2017-12-28 22:10:00	600	17797	descending	59.4	263.4	97.4	24	6781	Y
40304	2017-12-26 00:38:00	2017-12-26 00:46:47	2017-12-29 00:22:00	900	17798	ascending	-62.2	52	97.4	48	6780	Y
40304	2017-12-25 09:38:00	2017-12-25 09:43:22	2017-12-28 20:59:00	1020	17797	descending	-14.7	266.5	97.5	72	6779	Y

Figure 7. TIP messages for SL-24 PLAT, 40304

7. CONCLUSION

The 18 SPCS processes reentries with procedures that have been developed over decades. This includes alerting other agencies and the public of reentering objects and what areas may be at risk.

8. REFERENCES

[1] Jenkin, A.B., McVey, J.P., Wilson, J.R., Sorge, M.E., “Tundra Disposal Orbit Study,” Proceedings of the Seventh European Conference on Space Debris, Darmstadt, Germany, April 18-21, 2017.

9. AUTHORS

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